BoF: Object Life-Time Handling in Driver Subsystems

Bartosz Golaszewski

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About me

- Linux kernel developer for the Qualcomm Landing Team at Linaro
- 15 years of embedded linux experience
- Maintainer of the GPIO subsystem
- Author and maintainer of libgpiod
- Open-source contributor to many other projects
- Interested in complex software architecture

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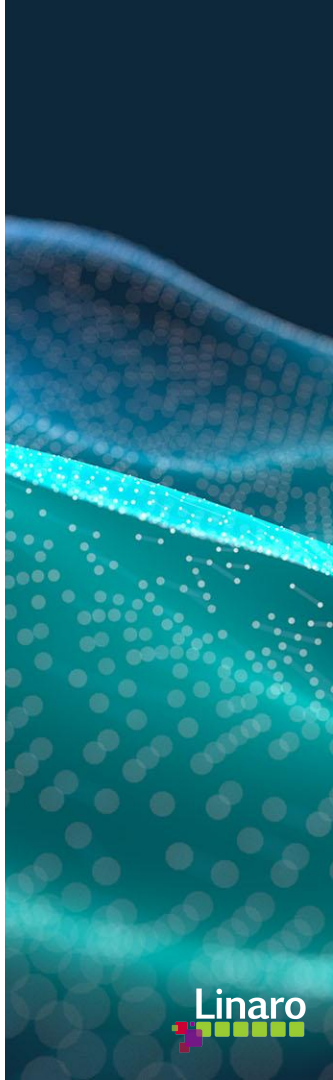
Background

- Laurent Pinchart at Linux Plumbers 2022
  - “Why is devm_kzalloc() harmful and what can we do about it”
  - https://www.youtube.com/watch?v=kW8LHWIJPTU
- Bartosz Golaszewski at FOSDEM 2023
  - “Don't blame devres - devm_kzalloc() is not harmful
  - Use-after-free bugs in drivers and what to do about them.”
  - https://archive.fosdem.org/2023/schedule/event/devm_kzalloc/
- Wolfram Sang at EOSS 2023
  - “Subsystems with Object Lifetime Issues (in the Embedded Case)”
  - https://www.youtube.com/watch?v=HCiJL7djGw8
- Bartosz Golaszewski (again) at Linux Plumbers 2023
  - “Improving resource ownership and life-time in linux device drivers”
  - https://www.youtube.com/watch?v=9JZDKBT0nZc
- Wolfram Sang (again again) at Open Source Summit Japan 2023
  - “Object Lifetime Issues - a Threat for Safety?”
  - https://www.youtube.com/watch?v=nnDl89Y7B0k

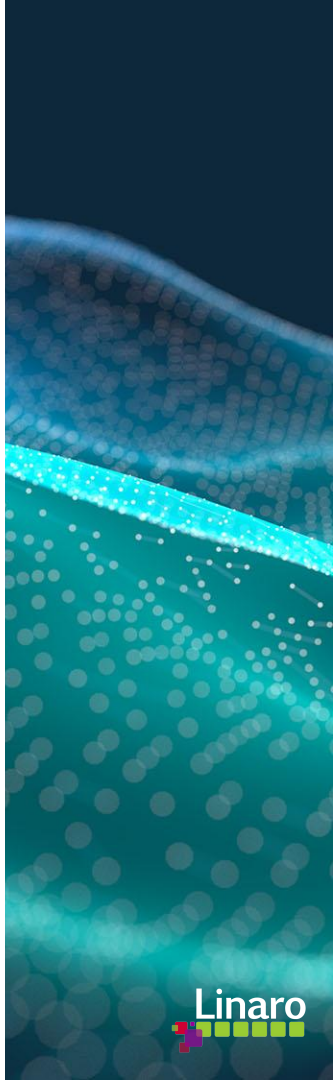
Typical resource provider driver

```
static int foo_probe(struct platform_device *pdev)
{
	struct foo_data *data;
	int ret;

	data = devm_kzalloc(&pdev->dev, sizeof(*data), GFP_KERNEL);
	if (!data)
		return -ENOMEM;

	return devm_bar_subsys_register(&pdev->dev, data);
}
```



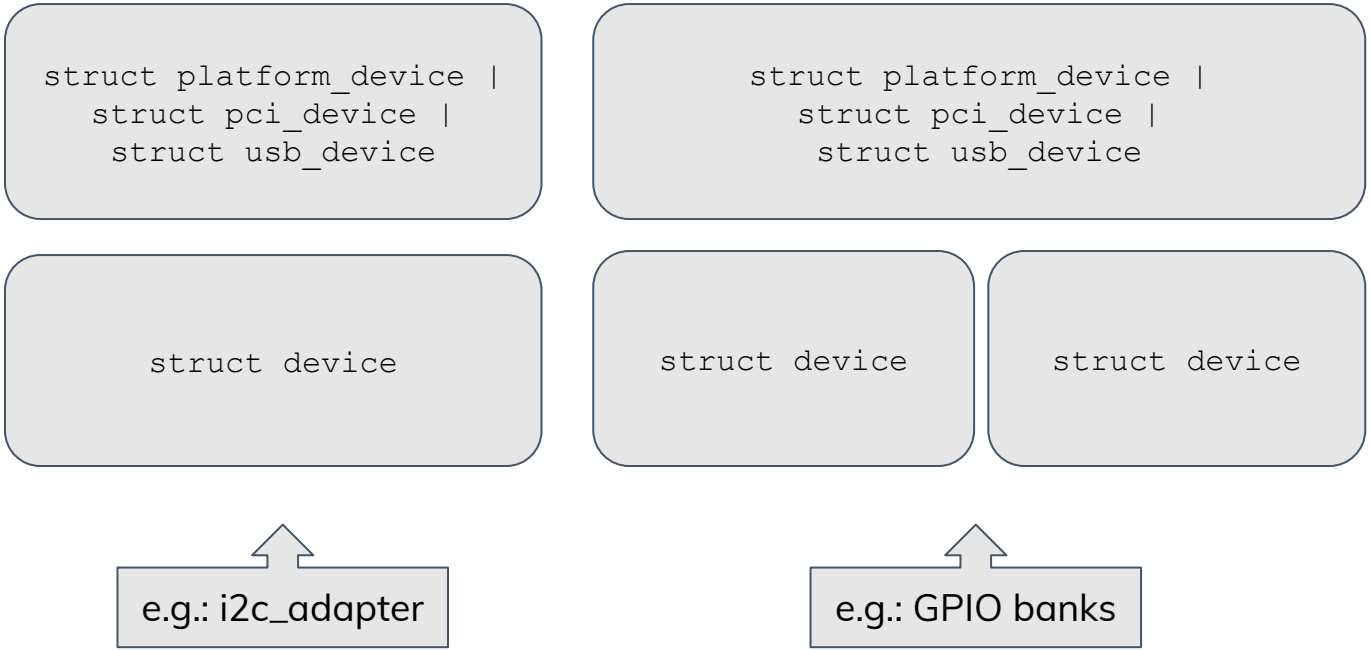
Problem

- Drivers allocate memory for `struct device` in `.probe()` and free it in `.remove()` but `struct device` is reference counted
- Some subsystems just crash, others implement various workarounds
- Solution is easy: `struct device` must survive driver unbind
    - More broadly: the subsystem must be resistant to provider data being destroyed at any moment
- Some subsystems get it right(ish)



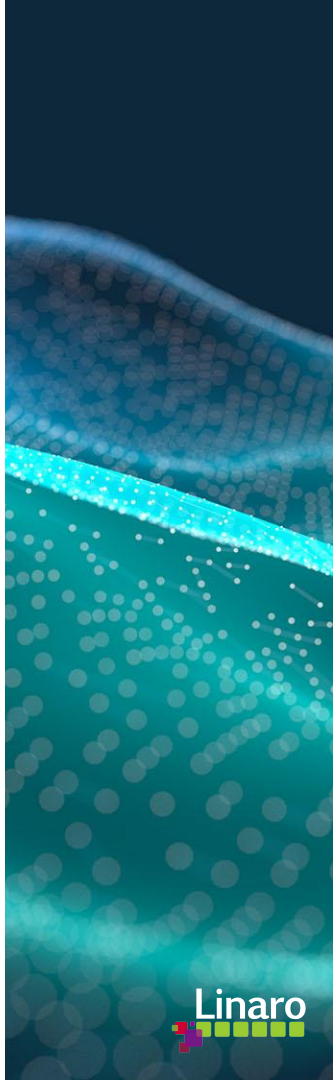
On `struct device`

- Common pattern in device drivers - physical and logical devices:



Agenda

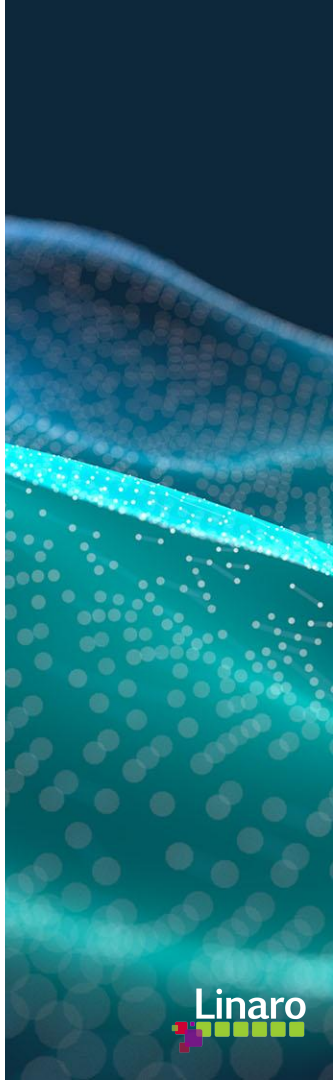
1. **Split responsibility between the subsystem core and provider driver**
2. Allocate driver and subsystem data in the driver and hand it over to the subsystem core
3. Read-only config structure
4. ???
5. Can we rely on device links exclusively?



Split responsibility

- Subsystem defines an “implementation” structure for the provider driver to allocate and register, its life-time is tied to that of the driver

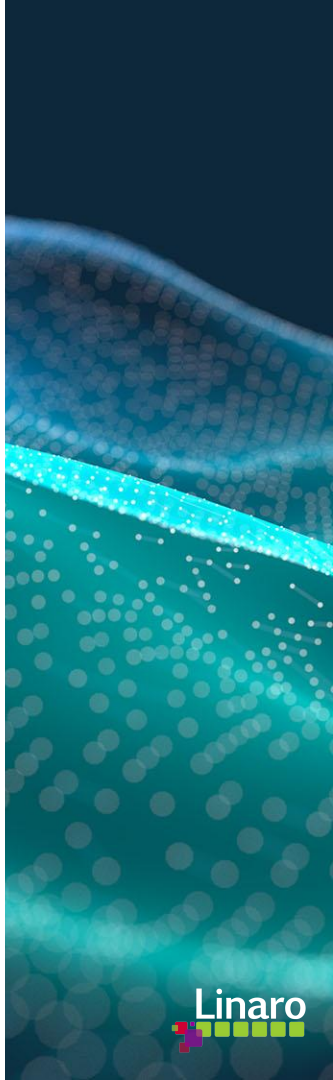
```
struct bar_impl {
    const char *name;
    int (*flob)(struct bar_device *);
};
```



Split responsibility

- Driver “fills” the structure and registers it with the subsystem

```
struct bar_impl *impl;

impl = devm_kzalloc(dev, sizeof(*impl), GFP_KERNEL);
if (!impl)
     return -ENOMEM;

impl->name = "foo";
impl->flob = foo_flob;

return devm_bar_register(dev, impl);
```



Split responsibility

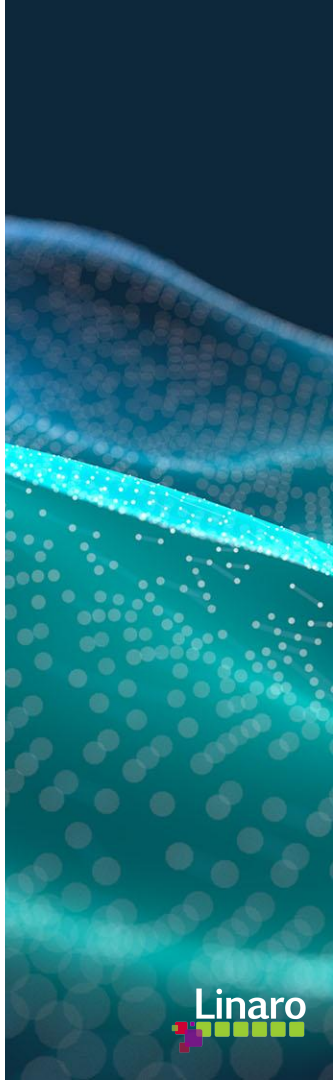
- Subsystem core allocates any additional data inaccessible to the driver, including the reference counted logical `struct device`

```
struct bar_device {
     struct device dev;
     struct bar_impl __rcu *impl;
};

int bar_register(struct bar_impl *impl) {
     struct bar_device *bdev;

     bdev = kzalloc(sizeof(*bdev), GFP_KERNEL);
     if (!bdev)
          return -ENOMEM;

     device_initialize(&bdev->dev);
     bdev->impl = impl;

     return 0;
};
```

Split responsibility

- Subsystem guards the implementation pointer

```
int bar_flob(struct bar_desc *desc)
{
	struct bar_device *bdev = desc->bdev;
	struct bar_impl *impl;

	guard(srcu)(&bdev->srcu);

	impl = srcu_dereference(bdev->impl, &bdev->srcu);
	if (!impl)
		return -ENODEV;

	return bdev->impl->flob(bdev);
}

void bar_unregister(struct bar_device *bdev)
{
	bdev->impl = NULL;
	synchronize_srcu(&bdev->srcu);
}
```



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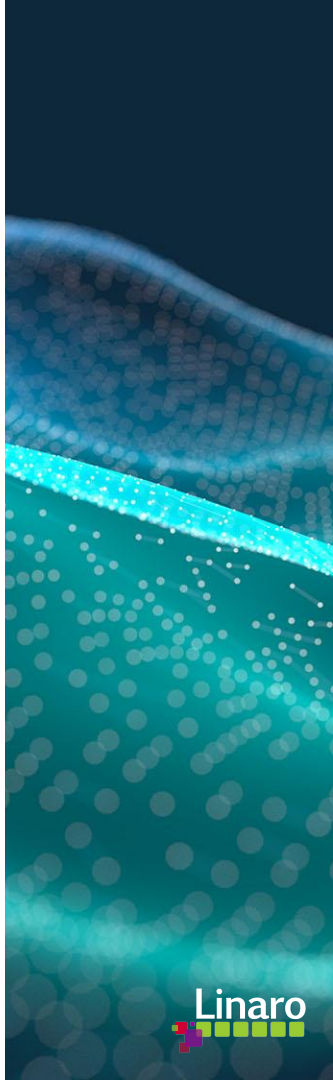
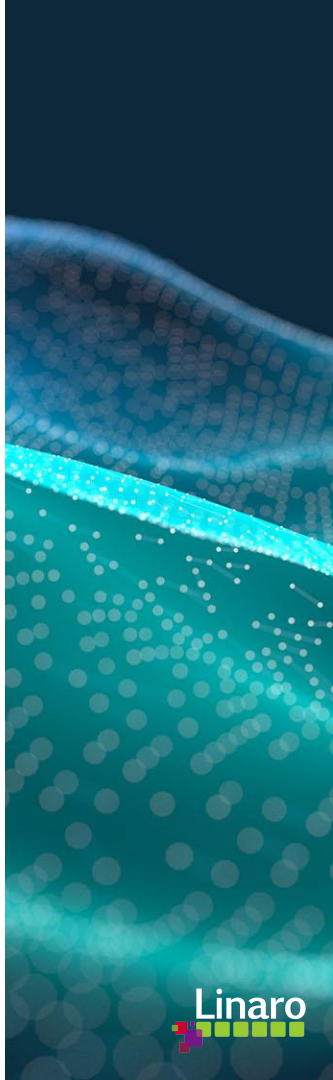


Handover of subsystem data

- Subsystem defines a structure containing all data required to make the provider driver work

```
struct bar_ops {
    int (*flob)(struct bar_device *);
};

struct bar_data {
    const char *name;
    struct device dev;
    const struct bar_ops *ops;
};
```



Handover of subsystem data

- Driver allocates the memory for the structure using a non-managed, subsystem-specific interface (and **DOES NOT** free it in `.probe()`) and registers it with the subsystem, effectively handing it over to it.

```
static int foo_probe(struct platform_device *pdev)
{
	struct bar_data *bdata;
	int ret;

	bdata = bar_alloc_data();
	if (!bdata)
		return -ENOMEM;

	ret = devm_bar_register(bdata);
	if (ret) {
		bar_free_data(bdata);
		return ret;
	}

	return 0;
}
```

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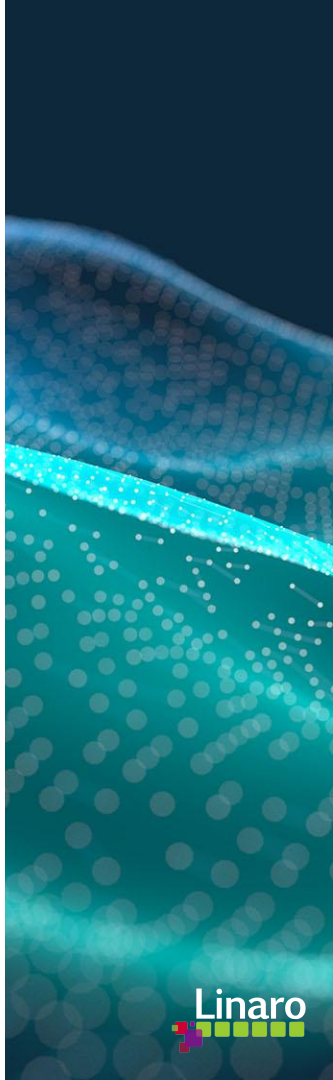
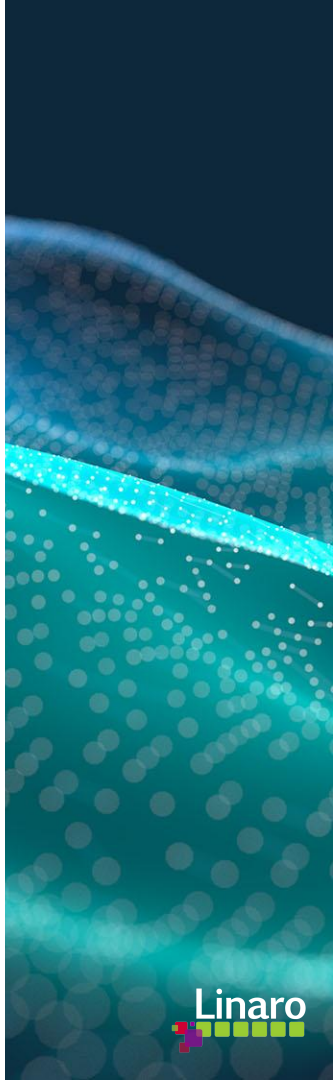


Read-only config structure

- Variant of the “split responsibility” approach
- Subsystem defines a config structure for the provider driver to provide during registration with the subsystem

```
struct bar_config {
    const char *name;
    int (*flob)(struct bar_device *);
};
```



Read-only config structure

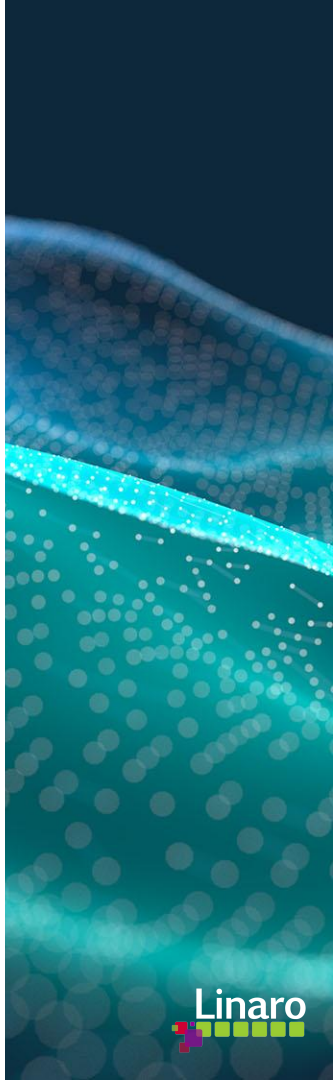
- The structure can be freed after that
- All relevant data is copied and managed by the subsystem

```
struct bar_config config;

memset(&config, 0, sizeof(config))

config.name = "foo";
config.flob = foo_flob;

return devm_bar_register(dev, &config);
```



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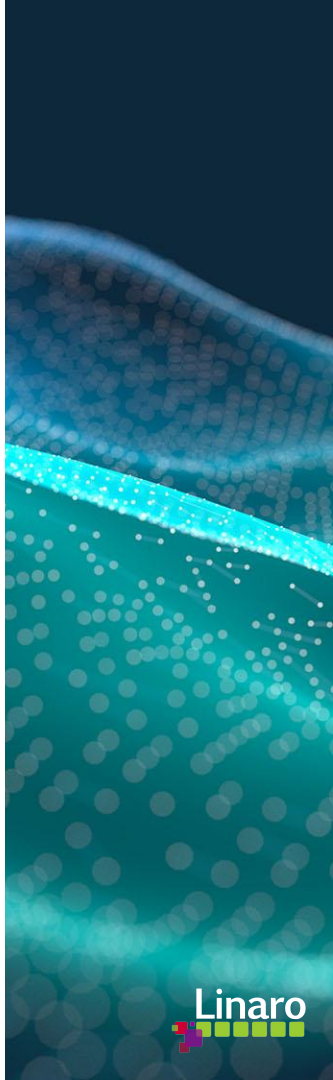

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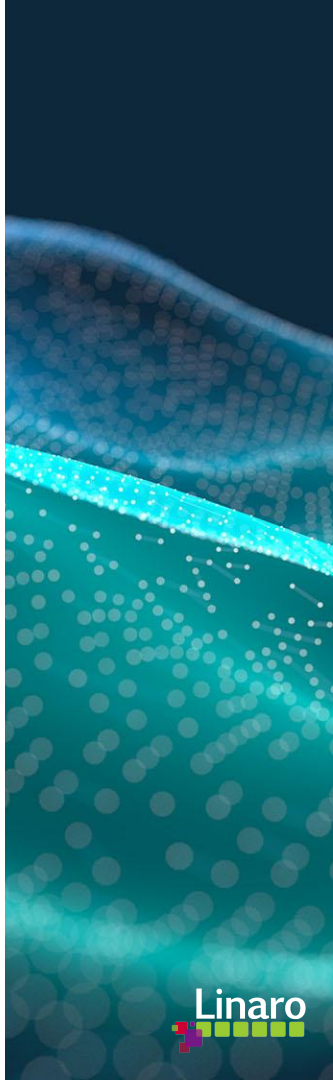
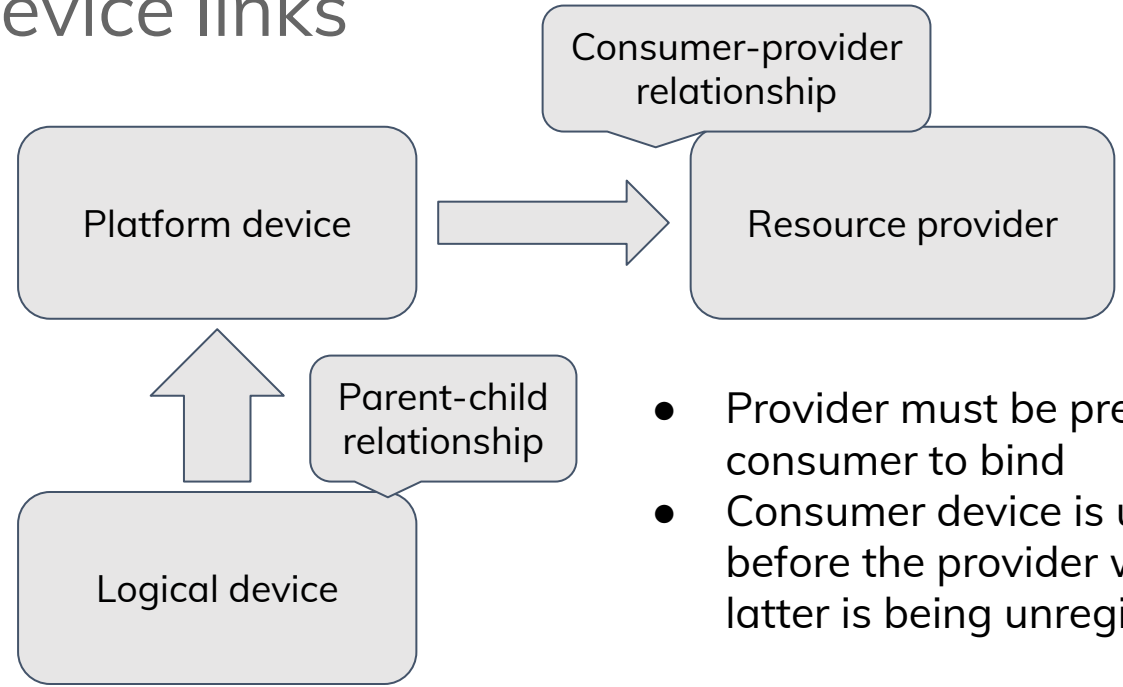


Device links



- Provider must be present for consumer to bind
- Consumer device is unbound before the provider when the latter is being unregistered

Thank you

Visit www.linaro.org
Reach out to me at bartosz.golaszewski@linaro.org